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Small Energy Efficient Systems: The Key to Energy Security of the EU

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Abstract:

Purpose: *The development of high computing power in a compact form factor in conjunction with alternative energy sources allows you to build "smart" energy networks even within a separate household, increasing energy efficiency and energy security. However, distributed energy is faced criticism for widespread implementation, as well as with other factors that do not allow accelerating the development of technologies. Therefore, the purpose of this article is to select and analyze the most effective tools for the functioning of distributed energy systems using the example of EU countries.*
Design/Methodology/Approach: *The historical aspects of the development of small energy systems, the legislative definition and the range of possibilities of these systems, as well as the scientific and technological research units carried out using distributed energy systems, are considered in this research.*
Findings: *The article actualizes the importance of alternative energy sources as one of the promising directions for the development of the energy system of EU countries.*
Practical Implications: *Alternative energy is a key component of small energy technologies, due to environmental friendliness, adaptability and the ability to install almost any dimension of energy-generating equipment. Also, this energy source is inexhaustible, which means it reduces the energy dependence of countries on the extraction and/or import of raw materials for energy production and increases the energy security of the energy network.*
Originality/Value: *It is worth noting that distributed energy has great potential for distribution and development in the long term, which is necessary to study all the positive and negative aspects of small energy systems in order to minimize the negative factors of small energy and strengthen the individual will opt for distributed energy and then disseminate successful experience everywhere.*

Keywords: *Energy efficiency, energy security, alternative energy, energy in EU countries.*

JEL codes: *J01, P18, P48.*

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1. Introduction

Electricity is one of the foundations of modern industry. No industry, enterprise or household can function without energy consumption. Not only the comfort of an individual, the performance of other systems of a household and/or enterprise but also human life and safety depends on the uninterrupted and stable incoming heat and energy flow. Therefore, issues of energy efficiency and energy security are among the most acute and relevant in the 21st century. The countries of the European Union (henceforth - EU) are among the most energy-dependent countries in the world since they have a strong imbalance between the extraction of the necessary raw materials for energy generation and the total amount of energy generated in these countries. The proliferation of smart gadgets, the advent of electric vehicles and the high rate of development of production in the new EU member states increase energy imports from year to year. And although EU countries can supply the growing demand for energy in the future, to ensure energy security, experts note the need to create energy systems that can autonomously provide at least the minimum level of heat and electricity generation in case of interruptions in the supply of raw materials. For this purpose, in recent years, sources of energy generation have been actively diversified in the EU and almost all types of generation have been used from traditional raw materials (coal, oil products, gas, etc.), nuclear power plants to renewable energy sources. It is the latter becoming more and more relevant in demand in modern times (European, n.d.).

According to the forecasts of the development of the European Union until 2050, the European part of the continent of Eurasia should become climate neutral and EU countries should exclude fuels that pollute the atmosphere, except for natural gas and nuclear energy. The rest of the power system should be built exclusively on renewable energy. This trend is undoubtedly evaluated in a positive way, however, how to ensure the massive proliferation of nuclear power sources even in areas where the use of traditional raw materials seems the least expensive? The experts of the region turn to distributed energy. Such networks use many technologies and mechanisms for optimizing energy consumption, which, together with alternative energy sources, will reduce the financial burden, up to positive "profitable" values, when selling surplus energy (Investigation, 2017; Simon, 2018; Nagimov *et al.*, 2018). But why exactly are distributed energy systems distinguished as the most energy-efficient and energy-safe? To answer this question, it is necessary to highlight the key features of modern small energy systems (Table 1).

Table 1. *Key features and specifications for small energy systems*

1.	Economic expediency	• Distributed energy systems are highly energy-efficient and non-volatile from external supplies of raw materials; • In special climatic zones, the use of alternative energy in conjunction with the introduction of small energy systems is an economically more rational solution than the supply of traditional raw materials with the organization of storage facilities and/or regular energy purchases; • Many systems are designed for the reverse sale of energy back to the network, which allows you to receive income from the generation of own energy.
2.	Operational features	• High energy security through equipment monitoring and energy control; • High environmental safety and climate neutrality; • Almost complete elimination of power outages and network voltage instability; • It has the potential for further development and increased efficiency; • It is universal and can be used both in large settlements and as single households isolated from central heating and energy networks; • Scalability of energy generation sources allows increment of additional production if necessary; • It is possible to combine individual energy clusters into a single network, with the possibility of "smart" energy redistribution; • Reduces the load on centralized power grids; • Provides auxiliary benefits, including voltage support and stability, reserves for unforeseen circumstances and the possibility of starting in the "autonomy" mode (the ability of the generating unit to switch from a shutdown state to a working state and start power supply without using an electrical system).
3.	Adaptability and efficiency	• The modularity of the system provides the greatest energy efficiency; • Smart grids can ensure the stability of the energy flow for volatile objects, including data centers, social facilities, etc.; • The system's educability helps to better improve the individual blocks of the system.

Source: *Compiled by the author according to Distributed Energy System (2016).*

European countries have begun the fundamental process of transforming the current power supply system. The transition to an increase in the share of renewable energy sources in the total generation volume and the trend towards a more decentralized energy supply requires the creation of technologies that allow controlling every stage of energy generation, transmission and use in small power systems. This requires not only measuring equipment and software, but also a enough data hosting, computing power for analysis and a place for collecting and storing information. Together, the above technologies form a system identified as a Smart Grid. Most of the tools for improving network efficiency operate within the framework of the Smart Grid concept. According to the international dictionary, this term is characterized as an automated system that can independently monitor and control the equipment included in it and to regulate in order to maximize energy efficiency (Ledin, 2010; Polyakova *et al.*, 2018; 2019).

Another dictionary describes the development prospects of this system in the following words, “Smart Grid” is a set of technological solutions that are already at this stage of technology development capable of analyzing data and selecting the most optimal options for maximizing energy efficiency, and in the future will be able to learn from other similar systems and produce self-education based on the complexity of information data. Smart-Grid System includes:

- Integrated Electrical Systems;
- Smart distribution;
- Smart transmission;
- Smart retail and consumer systems.

The European Laboratory (DERLab) advocates accelerating the implementation of distributed energy systems in the EU and, in the long term, around the world. Acceleration of the introduction of small energy systems is ensured by the unification of technology and software, and the laboratory is developing proposals for legislative adjustments. Today it is the only European agency that regularly monitors and updates data on small energy systems. The Center for European Small Energy Research (DERlab) was founded for the above purposes as part of the meetings of the European Energy Congress and is funded from the EU budget. One of the functional areas of research is the Network of Excellence (NoE), which supports coordination and organizes access for Europeans to research at universities, institutes, academies, and other institutions as part of a program to support the fuel and energy complex of the European Union. In 2019, DERlab network united twenty distributed energy research institutes (Jimenez and Hatziargyriou, 2006).

The geography of the database of scientific centers is extensive; sixteen countries from Europe and the United States of America function in the program. With various activities in research, networking, and awareness-raising, the association promotes pre-regulatory research conditions for a more environmentally sustainable capable electricity generation in the future (Enhancement, 2010). Since 2018, DERlab and its members have been working together on standardized requirements and quality criteria for grid integration in small energy systems around the world. Electric Grids of the Future (SmartGrids ETP) brings together key stakeholders from the grid sector, network operators, energy generating companies, technology providers, the research community, regulators and related European and global organizations, platforms and initiatives. In autumn 2012, the European Secretariat joined DERlab, which supports the work and activities of the platform.

Smart Grids ETP formulates suggestions and recommendations for the modernization of the European power grid as part of the SET-Plan and organizes activities to familiarize households and enterprises with the use of small energy. DERlab holds seminars and public speeches to popularize small-scale energy, which is related to the current strategic processing of the development of distributed energy systems. The wide participation of stakeholders from industry, academic institutions, government, and other non-governmental institutions, establishes links between actual technology providers and potential consumers. DERlab also publishes scientific materials in these areas. One of the key publications of the platform, the Strategic Research Agenda 2035 (SRA 2035), published in early 2012, which describes the primary studies needed to improve the energy efficiency of distributed systems (European Distributed Energy, 2013).

2. Materials and Methods

The definition of energy efficiency tools for distributed energy is based on 3 main areas such as regulatory acts governing the functioning of small energy systems, technological capabilities, and scalability of the systems under consideration. Nevertheless, since small energy is a new direction in the development of energy economies, in different countries of the European Union there are not only differences in legal regulation, but also the construction of integrated small energy systems. So, in the statistics of different EU countries, under alternative home energy systems, systems can be indicated as single power plants that provide only part of the heat and electricity needed by the household, and complex solutions that ensure complete independence from centralized networks. Therefore, this study primarily presents relative indicators and investment data by country.

A special role in the analysis of the functioning of small power systems is played by the technological aspect. Many experts conclude that the control of energy flow and self-training of the system in the future will become one of the significant advantages over the traditional heat and power supply system.

3. Results and Discussion

Technological support for distributed energy systems plays a key role in energy efficiency and safety. From the totality of technological solutions, it will depend on how much the system can adapt to the current situation and how the energy distribution will be most effectively selected for each household. To begin with, we will consider the components of smart grids and define technologies to reduce energy consumption and losses during transmission from the generation source to the final object.

Clustering is one of the most efficient methods used to reduce energy consumption and extend the life of network equipment. The bottom line is that when designing a small energy system, energy heterogeneity is considered both in the selection of equipment and software when developing clustering protocols. Modern systems can automatically distribute energy flow by type of building and level of energy consumption. The system is part of the Smart Grid. At the first stage, the expected cluster links are determined by the relative levels of the initial and residual energy.

Then, in the second stage, the energy balance is determined to form the final set of technological solutions. Energy consumption is distributed according to the efficiency and safety protocols formed earlier; for this, artificial modeling of all probable processes is carried out and the simulation results are used to achieve longer periods of energy flow stability than other typical clustering protocols in heterogeneous scenarios (Han *et al.*, 2017).

3.1 Optimization of Energy Use

Among renewable energy sources, it is especially worth highlighting alternative energy sources (henceforth - AES). Solar energy, wind energy, bioenergy and other types of alternative energy form the basis of small (distributed) energy systems. These systems are compact and can be used not only at the regional and municipal levels but also by individual households and single buildings. Of course, when it is necessary to provide energy for one household, the size and cost of a possible source of energy is a priority. Alternative energy sources will be most relevant, as they are modular and have different output powers. Also, depending on the geographical and climatic features of the region, you can choose the most optimal type of heat and electricity generator.

3.2 Energy Quality Measurement System (PQI)

This system is used for modern distributed energy resources. The rapid growth of renewable and distributed energy production sites gives equipment manufacturers financial opportunities to invest in further development of technologies and conduct research and technological development (henceforth - RTD). But this expansion also has the flip side that was mentioned earlier - a new model of small energy creates unforeseen consequences: as the distributed energy resources expand, it becomes more difficult to measure the quality of energy networks and electricity.

PQI system was created and designed with the expectation of processing and standardization of measured indicators. This system has been approved by the International Electrotechnical Commission (IEC), which helps electric companies and contractors to explore energy networks and carry out equipment specifications for specific tasks. This system also helps power grid companies to modernize and repair equipment in a shorter time, as all information can be processed and translated by PQI into common standards.

The digitization of electrical metering is another factor determining the need for consistent measurements of the quality of electricity. Although most digital meters may report some indicators, these measurements may vary significantly from manufacturer to manufacturer (Simon, 2018). To increase the effectiveness of control over current small energy systems in the EU, it was necessary to carry out some standardizations, in which equipment operating in different ranges of electric power could collect and analyze data on current power and project the results to other flows. The first ideas were introduced back into the regulatory system of the Eurozone in 2003 - the standard for electric power quality control IEC 61000-4-30. Today, most reputable manufacturers of electricity meters have products that comply with this standard. This standard focuses on methods for measuring the quality of electricity, but it does not consider the need for a standard process for verifying the performance of measurements of electricity quality following IEC 61000-4-30 (EU statistical review, n.d.). Thus, we can distinguish some tools that are used when choosing the most optimal model for building a distributed energy system:

- A comprehensive review of electricity regulation in the EU Member States;
- Analysis of possible innovations and perspective development of electric networks;
- Cost-benefit assessment of networks for widespread use;
- Analysis of regulatory mechanisms for economically viable small network systems;
- Recommendations and guidelines for improving the regulatory framework for distribution networks (Strasser *et al.*, 2012).

4. Conclusion

In conclusion, it is worth noting the most effective mechanisms for improving the energy efficiency of distributed systems in the countries of the European Union as presented in Table 2.

Table 2. *Effectiveness of distributed power tool*

№	Tool set	Tool
1.	Energy efficiency	• Control and optimization of energy flow; • The adaptability of the system to temperature, climatic, individual characteristics of the economy; • Collection and storage of analytical data; • Interaction with other small energy systems;

2.	Energy security	• Installation of antivirus and security software; • Implementation of machine learning algorithms for countering internal and external threats; • System for stopping and disabling unstable devices and preventing network congestion; • The decrease in dependence on centralized supplies of raw materials and, as a result, reduction in import costs.
3.	Economic efficiency	• Energy-flow monitoring system; • Minimization of energy losses during transmission and storage; • Implementation of excess energy in the central network; • Purchase of additional energy during temporary periods with cheaper billing.
4.	Environmental friendliness	• Creation of climate-neutral energy generators; • Minimizing emissions of harmful substances and heat into the atmosphere; • The use of environmentally friendly materials when creating distributed energy systems.

Source: *Compiled by the author according to Fleming (2019).*

Summing up, we can say that the tools used to improve energy efficiency and energy security in the distributed energy systems of the EU countries are estimated by the expert community as highly efficient. In the next few years, the share of energy produced by distributed energy systems will increase, and in the long run, it will surpass stations at traditional sources. Separately, it is worth assessing the potential of machine learning systems and the use of artificial intelligence to optimize energy consumption and build more advanced models of energy generation and consumption (Distributed Energy System, 2016).

However, due to the heterogeneity of the financial security of citizens of different EU countries, the introduction of small energy systems in some regions may be difficult due to the high cost of installing the equipment. Reducing primary financial costs and tax incentives for the transition to distributed energy will accelerate the process and positively affect the energy security of the entire European Union.

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